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245 BAEL

SUSANTA K. ROY

Bael (*Aegle marmelos* (L.) Corr.) is an important indigenous fruit of India. The importance of bael fruit lies in its curative properties, which make the tree one of the most useful medicinal plants of India.

19.1 Composition and Uses

The ripe fruit is laxative and unripe fruit is prescribed for diarrhoea and dysentery. It has a great demand from native systems of medicine such as *Ayurvedic* (Kirtikar *et al*, 1935).

Various chemical constituents, viz., alkaloids, coumarins and steroids have been isolated and identified from different parts of bael tree such as leaves, wood, roots and bark (Chatterjee and Roy, 1957 and 1959 ; Chatterjee and Bhattacharjee, 1959, Shoeb *et al*, 1973). Some studies have also been made on the essential oils of the leaves (Baslas and Deshpande, 1951) and on the physical properties and uses of gums in the preparation of adhesives, water-proofing and oil emulsion coating (Badar-ud-Din, 1950 ; Haksar and Kendurkar, 1961).

The baelfruit is one of the most nutritious fruits. According to Gopalan *et al*, (1971), it contains 61·5 gm water, 1·8 gm protein, 0·39 gm fat, 1·7 gm minerals, 31·8 gm carbohydrates, 55 mg carotene, 0·13 mg thiamine, 1·19 mg riboflavin, 1·1 mg niacin and 8 mg vitamin C per 100 gm of edible portion. No other fruit has such a high content of riboflavin.

Chemical analysis of bael seeds revealed that the seed contained 62 per cent protein (water soluble 2% and 60% insoluble), 32 per cent oil, 3 per cent carbohydrate and 3 per cent ash (Banerjee and Maiti, 1980). Marmelosin is most probably the therapeutically active principle of baelfruit. It has been isolated as a colourless crystalline compound (Dixit and Dutt, 1932).

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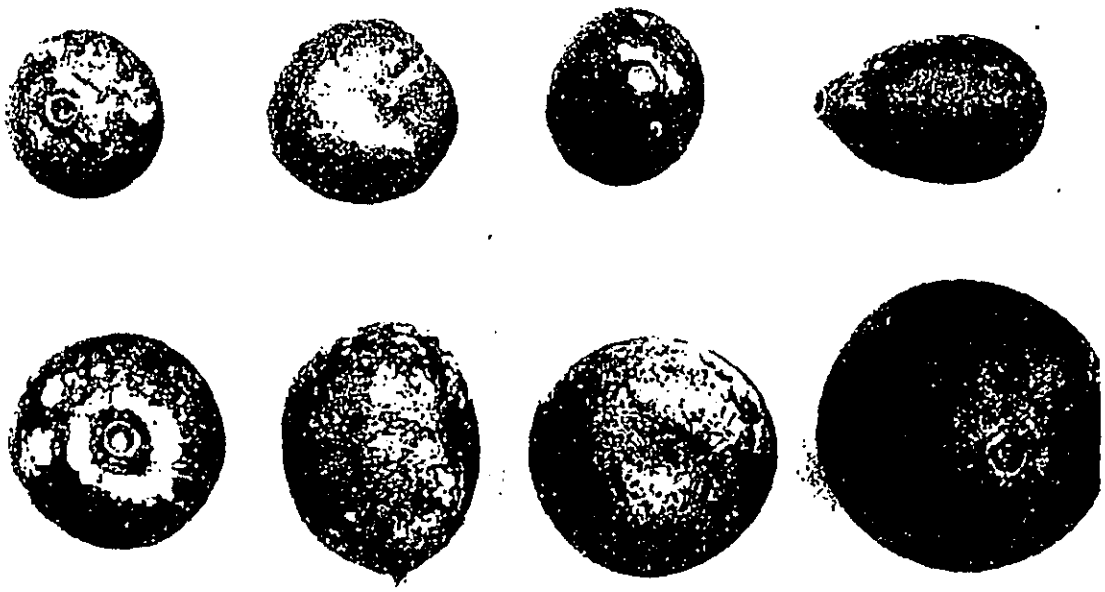

Bael fruits of different varieties

A bael tree

Bael, because of its hard shell, the mucilaginous texture and numerous seeds, is difficult to eat out of hand and is not popular as a dessert fruit. In the excellent flavour and nutritive and therapeutic values of the baelfruit lies an untapped potentiality for processing (Roy and Singh, 1979a).

19.2 Origin and Distribution

The bael has been known in India from prehistoric times. The leaves of the tree are traditionally used as sacred offering to 'Lord Siva' according to Hindu custom. In the epic ages, such as those of the 'Ramayana' baelfruit was known. Om Prakash (1961) found mention of the bael in Vedas and also in early Buddhist and Jain literatures.

It grows throughout the Indian peninsula as well as in Sri Lanka, Pakistan, Bangladesh, Burma, Thailand and most of the South-East Asian countries.

19.3 Species and Varieties

Species

The genus *Aegle* belonging to the family Rutaceae, consists of 2 or 3 species, and the generic name is of Greek origin. The specific name, *marmelos* is a Portuguese one.

The tree is deciduous, 6-8 m in height, with trifoliate aromatic leaves and the branches usually have long straight spines. The bark is shallowly furrowed and corky. The flowers are 2 cm wide, sweet scented and greenish white, the calyx is shallow with 5 short, broad teeth, pubescent outside. There are 5 petals (rarely 4), which are oblong oval, blunt, thick, pale greenish-white, dotted with glands. Stamens are numerous, sometimes coherent in bundles. The ovary is oblong-ovoid slightly tapering, the axis being wide. Cells are many, 8-20, small and arranged in a circle, with numerous ovules in each cell. The fruit is usually globose with the pericarp nearly smooth, greyish-yellow, thick, 2-3 mm hard and filled with soft pulp. Seeds are numerous, compressed and arranged in closely packed tiers in the cells (seed cavity) surrounded by mucilage. The testa is white with woolly hairs. The embryo has large cotyledons (Reuther *et al*, 1967).

Varieties

There are no standard names of varieties of bael. They are generally named after the names of the locality where they are most easily available. Reports on the varieties available so far are mainly from Uttar Pradesh, Bihar and West Bengal (Singh, 1961 ; Teaotia *et al*, 1963 ; Jauhari *et al*, 1969 ; Jauhari and Singh,

1971 ; Mazumdar, 1975). Yield per tree, weight of fruit, number of seeds per fruit, thickness of rind, total soluble solids, total sugars and vitamin C of bael varied from 200 to 400; 1283 to 2818 gm, 74 to 207, 0·16 to 0·28 cm, 28 to 36 per cent, 11·74 to 16·89 per cent, and 13·4 to 22·7 mg/100 gm respectively. Roy and Singh (1978) studied 24 varieties from four different locations in India—Agra, Calcutta, Delhi and Varanasi. Fruits of different varieties were spherical, oblong, cylindrical, pear shaped, flat, etc., weight of the fruit varied from 360 to 1850 gm. The percentages of peel, seeds and fibre of the different varieties of bael were found to vary from 20·54 to 36·11, 0·81 to 5·55 and 1·31 to 4·10 respectively. The maximum edible portion obtained among the varieties studied was 77·25 per cent and minimum 56·12 per cent. The highest moisture content was found to be 62·70 per cent and the lowest 59·37. The percentage of total soluble solids, sugars and mucilages ranged from 31·0 to 35·5, 12·50 to 17·9 and 12.78 to 19·57 respectively. The ranges in acidity, pH, ascorbic acid and phenolics were found to be 0·31 to 0·42 per cent, 5·0 to 5·3, 7·68 to 18·20 mg/100 gm and 3,000 to 17,500 mg/100 gm respectively. The bael contains a substantial amount of phenolics, which contributes to its astringent taste. The organoleptic quality of bael depends upon the balance of mucilage, sugars and total phenolics. A high amount of sugars, particularly non-reducing sugars and low amount of phenolics and mucilage make fruit more palatable.

19.4 Soil and Climate

Bael tree is very hardy and can thrive well even in swampy, alkaline and stony soils having pH range from 5 to 10 (Jauhari and Singh, 1971). According to Davis (1930) bael tree grows even on poor clay soils where other trees fail. Bael trees can be grown up to an altitude of 1,219 m and are not damaged by temperature as low as −7°C.

19.5 Area and Production

There is no organised orcharding of bael in India. Its cultivation is restricted and it grows mainly wild or in temple gardens. The fruit is available in almost all the states of India, but most abundantly available in Uttar Pradesh, Bihar, West Bengal and Orissa. No data, however, is available regarding its area and production.

19.6 Propagation

Seed

Bael is usually propagated by seeds which are sown in June ; seedlings are transplanted a year later.

Vegetative propagation

Suckers

Bael propagated by seed seldom produces a plant true to type. It can be propagated through root suckers.

Budding

It can also be propagated successfully by budding on 1 or 2 year old root-stock. Experiments were carried out on patch budding, T-budding and chip budding at monthly intervals from July to October and from March to June. Percentage of budtake was higher with patch budding. Budding in the month of June or July gave best results (Singh *et al*, 1976 ; Moti Dhar and Chaturvedi, 1976).

Grafting

Baelfruit can be grafted onto a number of related plants, such as *Aegle fraeglegabonensis* and *Aeglopsis chevalieri* (Reuther *et al*, 1967).

Top working

Old and uneconomic bael tree can be turned into economic and vigorous one by top working. In this method, the tree is headed back 1 to 1½ metres above the ground level during March and new shoots emerge from the stump. A few healthy shoots are retained and desired scions budded on them in the month of June. In this way, inferior and old unproductive bael trees can be transformed into superior and remunerative fruit trees (Jauhari and Singh, 1971).

19.7 Cultivation

There is no recommendation for the preparation of soil and pit or system and methods of planting in bael trees. However, general method adopted in case of citrus plants can be successfully followed. Bael, being a minor fruit, no systematic work has yet been taken up on manuring, fertilisation, irrigation, intercropping, etc.

It was found that many bael trees in southern Florida were suffering from zinc deficiency. Application of small amount of zinc sulphate caused them to make a vigorous new growth with green leaves and favoured the setting and maturing of a good crop of fruit (Reuther *et al*, 1967).

19.8 Fruit Growth and Development

The growth rate of bael has three distinct phases ; the initial slow increase for one month followed by rapid increase for four months and then more or less a stationary phase until the fruits are harvested. From the respiratory studies

baelfruit can be classified as a climacteric fruit (Roy and Singh, 1980). Monthly observation on the morphological changes of bael, as observed by Roy and Singh (1979b) are given below :

Period after fruit-set	*Characteristics of the fruit*
One month (June)	Peel deep green and soft ; no seeds ; the flesh on exposure turns brown very rapidly ; fruit oblong.
Two months (July)	Peel deep green, soft and easily peeled by knife ; flesh light yellow, turns brown on exposure ; small soft seeds and thin mucilage noticed ; fruit oblong.
Three months (August)	Peel deep green, hard, difficult to peel by knife ; flesh light yellow ; seeds soft ; size increased ; mucilage thin ; fruit spherical.
Four months (September)	Peel deep green, very hard, impossible to peel by knife ; flesh light yellow ; seeds a little hard, kernel formation noticed ; mucilage fairly thin, cavity almost full of seeds and mucilage ; fruit spherical.
Five months (October)	Peel green, very hard and woody ; flesh yellow ; seeds hard with hairy growth on surface, kernel prominent ; mucilage fairly thick ; fruit spherical.
Six months (November)	Peel green, very hard and woody ; flesh yellow ; seeds very hard, hairy on surface, kernel prominent ; mucilage thick ; fruit spherical.
Seven months (December)	Peel light green, very hard and woody ; flesh deep yellow ; seeds very hard, hairy with full formation of kernel ; mucilage very thick ; fruit spherical.
Eight months (January)	Same as December.
Nine months (February)	Same as January.
Ten months (March)	Peel greenish-yellow ; faint smell of ripeness ; other characteristics as in February.
Eleven months (April)	Peel yellowish-green, hard and brittle ; flesh texture softer ; flavour of ripeness more prominent ; other characteristics as in March.
Fully ripe stage (8 days after harvest)	Peel yellowish ; pronounced ripe baelfruit flavour ; pulp sweet and soft ; fruit detaches easily from the stem end.

Fruit drop is a problem in baelfruit. Pramanik and Bose (1974) tried various growth substances, viz., 2, 4–D, GA_3, 2, 4, 5–T, etc., with different concentrations but could not prevent the fruit drop.

19.9 Pests and Diseases

There is no serious pest on bael.

Diseases

Patel *et al*, (1953) reported that bacterial shot-hole and fruit canker of bael is caused by *Xanthomonas bilvae*. The symptoms on the leaves are characterised by round, water soaked spots (0·5 mm) surrounded by a clear halo. Gradually, the spots increase in size (3 mm to 5 mm) and form brown lesions with saucer like depressions in the centre surrounded by oily, raised margin. The primary localised lesions all over the leaf are always followed by falling-out of the dead tissues leaving circular or slightly irregular perforation or shot-holes. The pathogens also infect the fruit, twigs and thorns.

19.10 Harvesting, Yield, Packaging and Storage

Seedling bael trees require seven to eight years to bear while budded plants start bearing at the age of four to five years. The number and size of the fruit increase with advance in age and size of the tree. Proper care is required for harvesting baelfruit. At the time of harvest, the tree generally gets defoliated and the fruits are completely exposed. The fruit should be picked individually from the tree with a portion of fruiting stalk and should not be allowed to drop. Harvesting by shaking the tree is discouraged as the fruits are likely to develop cracks on impact because of the very brittle peel.

The number of fruits per tree may go up to 200 to 400 at the age of 10 to 15 years. However, a crop of 800 to 1,000 fruits on 40 to 50-year-old seedling tree is not uncommon.

There is no recommended practice for packaging baelfruit. At present, the fruits are packed in gunny bags, baskets and wooden boxes and sometimes they are transported without any packaging.

In order to prevent fungal infection, it is highly desirable that the fruit should not develop any crack during packing, storage, transportation and marketing. The storage life of baelfruit could be increased from two weeks at 30 °C to 12 weeks at 9 °C. Marked physiological breakdown is noticed when storage temperature is below 9 °C (Roy and Singh, 1979c).

19.11 Breeding and Varietal Improvement

There is no systematic work on the breeding and varietal improvement on bael. However, bael provides an excellent scope for improvement of fruit quality by breeding as, in India, different strains are available. If the cultivation of bael is intensified after selecting an ideal variety, this fruit might emerge as a potential fruit for the processing industry.

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The Hepatoprotective Effect of Bael Leaves (Aegle Marmelos) in Alcohol Induced Liver Injury in Albino Rats

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Abstract: Herbal drugs are traditionally used in various parts of the world to cure different diseases. The Ayurvedic and Siddha medical systems are very famous medical practices in Indian traditional medicines. In the present research studies, Bael leaves (*Aegle marmelos*, family of *Rutaceae*) which are also called as Bilva in ancient Sanskrit was used as herbal drug and its hepatoprotective effect in alcohol induced liver injury in albino rat was evaluated using essential biochemical parameters. The experiments were performed with four groups of animals. The experimental animals were administered with 30% ethyl alcohol for a period of 40 days and the fine crude plant leaves powder was fed to animals for next 21 days. The observed values of TBARS (Thiobarbituric acid reactive substances) in healthy, alcohol intoxicated and herbal drug treated animals were 123.35, 235.68 and 141.85 µg/g tissue respectively. The results were compared with the standard herbal drug silymarin (133.04 µg/g tissue). The experimental results indicate that, the Bael leaves have excellent hepatoprotective effect. A similar experimental result was also observed in other biochemical parameters.

Keywords: Herbal drugs, Bael leaves, Alcohol toxicity, Liver injury and Albino rats.

Albino Ratlarda Alkolün Sebep Olduğu Karaciğer Yaralarında Bael Yapraklarının (Aegıe Marmelas) Hepatoproektif Etkisi

Özet: Bitkisel ilaçlar dünyanın çeşitli yerlerinde bir takım hastalıkların tedavisinde geleneksel olarak kullanılmaktadır. Hyurvedik ve Siddha medikal sistemleri Hint geleneksel tıbbının çok ünlü tıbbi uygulamalarıdır. Günümüzün araştırma çalışmalarında antik Sanskritte Bilva olarak adlandırılan Bael yapraklarının (Aegle Mammelas, Rutaceaeailesi) bitkisel bir ilaç olarak kulalnımı ve albinoratlarda alkolün sebep olduğu karaciğer yaralarındaki hepatopolektif etsinin gerçek biyokimsayal parametreler kullanarak hesaplanması incelenmektedir. Deneyler dört grup havyan üzerinde yapılmaktadır. Deney hayvanlarına 49 günlük periyotlarla % 30 etil alkol verilmektedir ve sonraki 21 günde de hayvanlar ham bitki yaprakları tozu ile beslenmektedir. Sağlıklı durumda, alkol verilmiş ve bitkisel ilaçlarla tedavi edilmiş hayvanlarda TBARS (Thiobarbituriliasit reauif maddeleri)'in gözlenen değerleri sırasıyla 123-35, 235-68 ve 141-85 Mg/g şeklinde bulunmuştur. Sonuçlar standart bitkisel ilaç silymarin (133.04 Mg-g dow) ile karşılaştırılmıştır. Deney sonuçları, Bael yapraklarının hepatoprotektif etkininin mükemmel olduğunu göstermektedir. Diğer biyokimyasal parametrelerle de benzer deney sonuçları gözlenmektedir.

Anahtar Kelimeler: Bitkisel ilaçlar, Bael yaprakları, Karaciğer yarası ve Albinoratlar.

Introduction

Indigenous plants have been the traditional source of raw materials for the manufacture of medicines. The diverse culture of our country is a rich source of traditional medicines, many of which one of plant origin scientific data on such plant derivatives could be of clinical importance (Gupta, 1994). The trend of using natural products has increased and the active plant extracts are frequently screened for new drug discoveries (Das et al., 1999).

Aegle marmelos, commonly known as Bael, is a spiny tree belonging to the family Rutaceae. It is an indigenous tree found in India, Myanmar, Pakistan and Bangladesh. The leaves, roots, bark, seeds and fruits are edible and medicinal values. The medicinal properties of this plant have been described in the Ayurveda. In fact, as per Charaka (1500 B.C) no drug has been longer or better known or appreciated by the inhabitants of India than the *Bael*.

The leaves of *Bael* are astringent, a laxative, and an expectorant and are useful in treatment of ophthalmia, deafness, inflammations, cataract, diabetes, diarrhoea, dysentery, heart palpitation, and asthmatic complications (Kirtikar and Basu, 1993). It has been claimed the leaf of *Aegle marmelos* posses contraceptive efficacy (Bhattacharyay, 1982). Fresh aqueous and alcoholic leaf extracts of *Aegle marmelos* were reported to have a cardio tonic effects in mammals (Haravey, 1968 and Nadkarni, 2000).

Aegle marmelos leaf extract has been reported to regenerate damaged pancreatic beta cells in diabetic rats (Das et al., 1996) and increased the activities of peroxidase in the liver tissues of Isoproterenol treated rats (Rajadurai et al., 2005). An aqueous decoction of the leaves has been shown to possess a significant hypoglycemic effect (Karunanayeke et al., 1984).

Aegle marmelos leaf extract was found to be a potential antioxidant drug, which reduces the blood sugar level in alloxan induced diabetic rats (Sabu and Ramadasan, 2004). It was found to be as effective as insulin in the restoration of blood glucose and body weight to normal levels on hyperglycemic state (Seema et al., 1996).

The ethanolic extract of *Aegle marmelos* leaf possesses anti spermatogenic activity (Sur et al., 1999) and aqueous extract of the leaf has anti motility action on spermatozoa in rats (Sur et al., 2002). Considering the diverse medicinal properties of *Aegle marmelos*, the present study was under taken to evaluate the hepatoprotective effect of Aegle marmelos in alcohol induced liver injury in experimental animal models.

Materials and Methods

Plant Material

Leaves of *Aegle marmelos* were collected from Thanjavur district of Tamil Nadu, India during the months of September – December. Fresh leaves were dried at 45^{0}C for 48 hours, powdered using electric grinder, and stored in a decicator. This fine crude powder was used as herbal drug.

Selection of Animals

In this experiments twenty four healthy male albino Wistar strains rats, 3 months of age, weighing 150 – 190g were selected for acclimation for a period of two weeks in laboratory animal house and maintained under standard conditions of temperature 27 ± 2^{0}C, relative humidity of 60 ± 5% and 12: 12 hour light: dark cycle prior to experimentation. The animals were fed with standard pellet diet and water ad libitum. The experimental animals were divided into four groups (G1, G2, G3 and G4) each contains six animals as per the drug treatment plan. First group served as control and the rest served as experimental groups. The ethics committee of Tamil University, Thanjavur, approved the protocol of the present study.

Drug treatment protocol

The fine powder of *Aegle marmelos* leaves were suspended in physiological saline and administered to the experimental animals intragastrically as per the following experimental protocol. The first group (Control) received small amount of physiological saline and the animals has free asses to standard feed and water for 40 days. The second group was intoxicated with 1mL of 30% ethyl alcohol once in a day in afternoon for 40 days. The third group was intoxicated with 1mL of 30% ethyl alcohol similarly as second group. Further, the animals were treated with the powder of *Aegle marmelos* herbal drug (1g / Kg. b. wt) twice a day (morning and evening) for 21 days. The fourth group served as reference animals, which were intoxicated similarly as third group

and treated with the standard drug silymarin at a dose (0.1g / Kg. b. wt) twice a day for 21 days.

Biochemical Assays

At the end of the drug treatment period, all the animals were anaesthetized by application of light chloroform and blood samples were collected from a group of animals from dorsal aorta by heparinized syringe in vacutainer tubes. Plasma was separated from the collected blood by centrifugation at 3000 g for 5 minutes. Separate blood samples were collected from another group of anaesthetized animals in glass test tubes and allowed to coagulate for 30 min. Serum was separated by centrifugation at 3000 g for 20 minutes. Plasma and serum samples were kept at – 20^{0}C for biochemical analysis.

The animals were sacrificed by cervical decapitation, the perfused liver of each animal was dissected out and washed with isotonic solution, and their wet weight was recorded. The liver homogenate was prepared using phosphate buffer solution for biochemical analysis. The biochemical parameters analyzed from serum, plasma and liver homogenate was presented in the Table 1.

Table 1. Biochemical parameters analyzed in liver homogenate, plasma and serum.

Biochemical parameters	References
Thiobarbituric acid reactive substances (TBARS)	Ohkawa et al., 1979; Esterbauer and Cheeseman, 1990
Reduced glutathione (GSH)	Sedlak and Lindsay, 1968
Superoxide dismutase (SOD)	Sun et al., 1998; Kakkar et al., 1984
Glutathione peroxidase (GPx)	Paglia and Valentine, 1967
Catalase (CAT)	Beers and Sizer, 1952
Vitamin – E	Barker et al., 1980
Plasma Ascorbic acid (Vitamin – C)	Besada, 1987; Noroozifar and Khorasani – Motlagh, 2003
Iron (Serum)	Yee and Goodwin, 1974
Copper (Serum)	Yee and Goodwin, 1974

Results and Discussions

Thiobarbituric acid reactive substances (TBARS)

The thiobarbituric acid assay is the most popular method of estimation of malondialdelyde level, which is an indication of lipid peroxidation and free radical activity. The increase in lipid peroxidation, a degradative process of membraneous polyunsaturated fatty acid has been suggested by the increase in malondialdelyde in ethanol induced toxicity in the liver. The increased lipid peroxidation results in changes in cellular metabolism of the hepatic and extra hepatic tissues, which ultimately leads to the whole cell deformity and cell death (Winrow et al., 1993).

The levels of TBARS in liver tissues of ethanol intoxicated rats were significantly elevated when compared to the level of TBARS in control animals. The administration of herbal drugs *Aegle marmelos* at the therapeutic doses (1g/Kg. b.wt) showed maximum reduction in TBARS level. The standard hepatoprotective drug Silymarin maintained the decreased lipid peroxidation level to the normal limits in the liver. The results indicate that, the herbal drug *Aegle marmelos* has very good hepatoprotective effect in liver damage. The results were presented in the Figure 1.

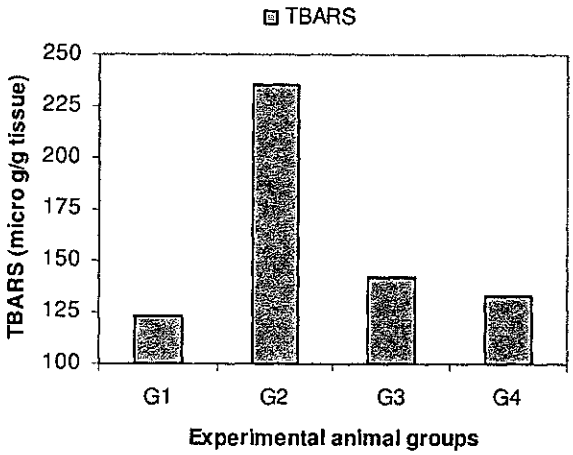

Fig 1. Effect of Aegle marmelos in TBARS level.

Glutathione Reductase (GSH)

It is an important source of reducing equivalents during oxidative stress generated by reactive oxygen species. The higher level of ethanol intake develops cirrhosis and liver damage by enhancing lipid peroxidation in the liver. Acetaldehyde the toxic metabolite of ethanol depresses the liver and plasma glutathione level by conjugating with the sulphydryl groups of glutathione (Comporti et al., 1973). In the present research work, we have observed the decreased level of glutathione in ethanol intoxicated rats.
The GSH depletion in hepatic mitochondria is considered the most important sensitizing mechanism in the pathogenesis of alcoholic liver injury. Treatment with *Aegle marmelos* herbal drug had significantly improved the level of glutathione both in plasma and lever tissues. Similar results also observed with the standard drug Silymarin. The results were presented in the Figure 2.

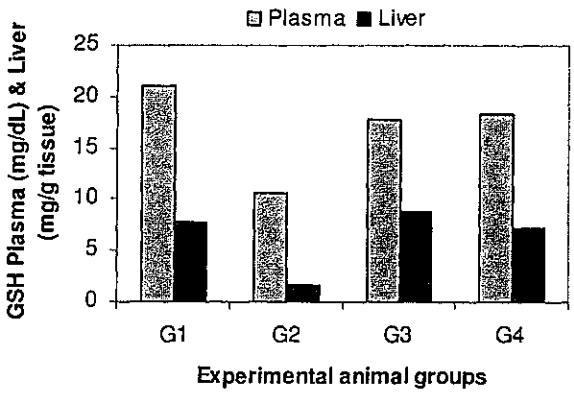

Fig 2. Effect of Aegle marmelos in GSH level in plasma and liver.

Superoxide dismutase (SOD)

SOD is the major attractive metalloprotein in the antioxidant family. The increased synthesis of superoxide dismutase against superoxide anion radical (O_2^-) production is an adaptive response of the cell to synthesis increased mitochondrial SOD through the stimulation of gene transcription (Das et al., 1997). The enzyme SOD was found to be decreased in ethanol intoxicated rats. This is due to the low level of Zinc (a metal constituent of the enzyme SOD) in plasma and liver tissues (Reding et al., 1984). The low level of zinc was also found in alcoholic liver cirrhosis (Henkin and Smith, 1972).

In the present study, significant decrease in the activity of liver SOD in ethanol intoxicated rat was observed. The therapeutic treatment with *Aegle marmelos* herbal drug significantly improved the level of SOD in liver. This result indicates that, the herbal drug promoted the hepatoprotection by elevating free radical scavenging activity. Similar results were also observed in Silymarin treated rats. The results were presented in the Figure 3.

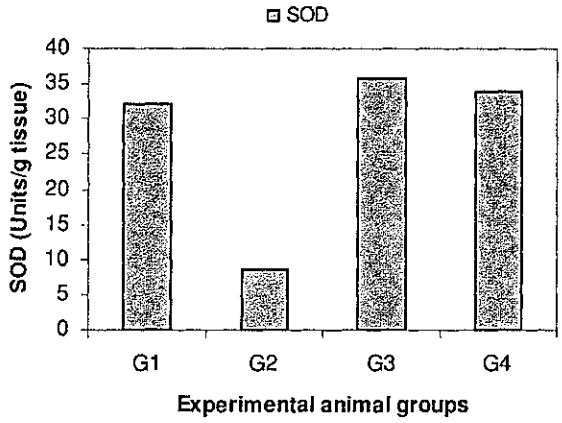

Fig 3. Effect of Aegle marmelos in SOD level.

Catalase (CAT)

The defensive antioxidant enzyme next to SOD is catalase. CAT traps the harmful hydrogen peroxide and converts into water and oxygen. The activity of catalase was found to be decreased in ethanol intoxicated rats. The inhibition of catalase activity during ethanol induced toxicity may be due to the increased generation of reactive free radicals, which can create an oxidative stress in the cells.

The administration of herbal drug *Aegle marmelos* inversed the catalase activity in the liver tissues and protected from the free radical induced oxidative stress (Rajashree et al., 1998). This results supports that, the antioxidant properties of the herbal drug was excellent as compared with the standard drug Silymarin. The results were presented in the Figure 4.

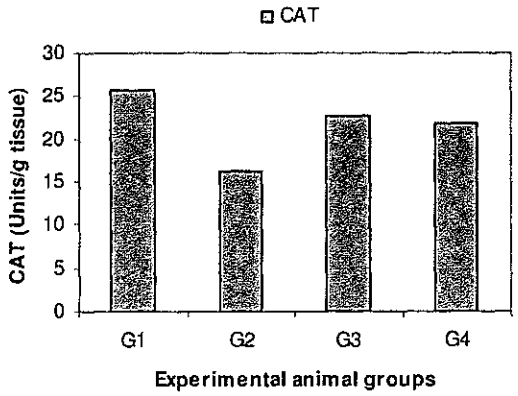

Fig 4. Effect of Aegle marmelos in CAT level.

Glutathione peroxidase (GPx)

GPx is a selenium dependent enzyme has high potency in scavenging reactive free radicals. In the present experiments, the levels of glutathione peroxidase activity in liver was elevated during alcohol intoxication to compensate the free radical scavenging effect utilized by the GSH as the substrate (Rajashree et al., 1998). When GPx activity in liver increased, the glutathione level is decreased in ethanol fed rats. Treatment with the herbal drug *Aegle marmelos* significantly decreased the level GPx to normal level. The standard drug Silymarin showed equivalent effect in the GPx level in the ethanol intoxicated rats. The results were presented in the Figure 5.

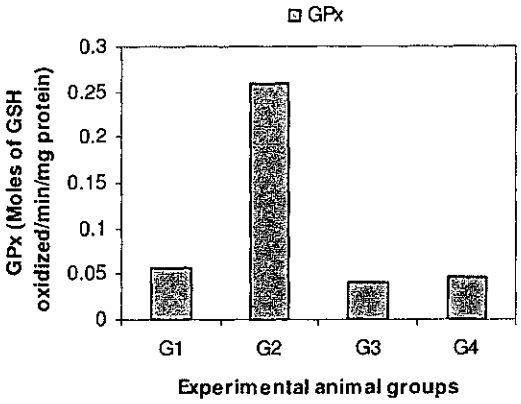

Fig 5. Effect of Aegle marmelos in GPx level.

Vitamin E and C

Vitamin E and C are natural antioxidants found in variety of plant materials. Ascorbic acid is most powerful antioxidant under physiological conditions. It exists mostly in the reduced form. It

cam directly scavenge superoxide, hydroxyl radicals and single oxygen. The ascorbic acid reduces H_2O_2 to water via ascorbate peroxidase reaction (Noctor and Foyer, 1998).

Vitamin – E is a chain breaking antioxidant. It can repair oxidizing radicals directly, and preventing the chain propagation step during lipid autoxidation (Serbinova and Packer, 1994). In our present research work, the decreased level of these vitamins was observed in ethanol intoxicated rats. This may be due to the high level of oxidative stress during the intoxication. The reduced form of glutathione substrate (GSH) is required for the regeneration of vitamin C, which is intern necessary for the regeneration of vitamin E (Thomas et al., 1992). The ascorbic acid functions as an aqueous phase antioxidant.

Therapeutic treatment with the herbal drug *Aegle marmelos* in intoxicated rats significantly increased level of vitamin E and C through the influence of GSH regeneration. Thus, the herbal drugs exert a beneficial effect in regenerating the GSH through the recycling mechanism of these vitamins. The standard drug Silymarin has similar effect in GSH regeneration. The results were presented in Figures 6 and 7.

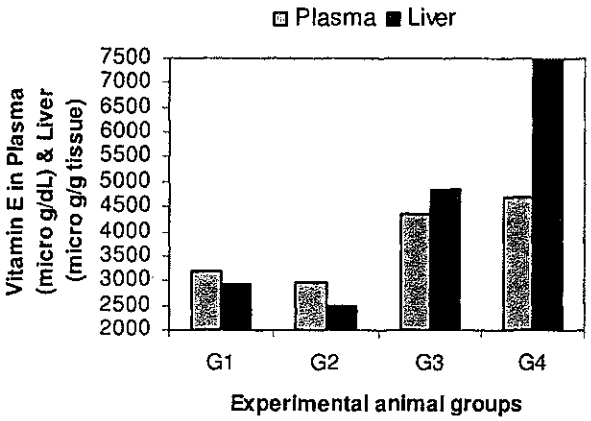

Fig 6. Effect of Aegle marmelos in vitamin E in plasma and liver.

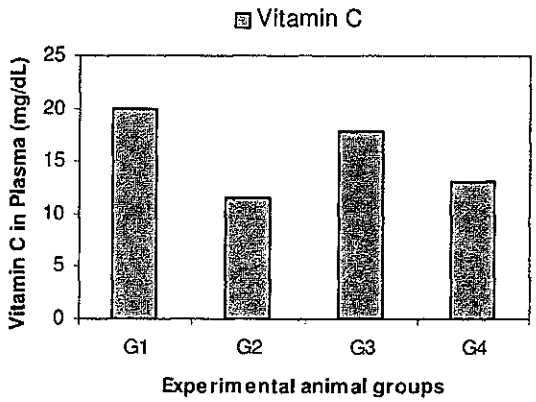

Fig 7. Effect of Aegle marmelos in vitamin C level in plasma

Iron and Copper

Serum iron and copper levels were significantly increased in ethanol intoxicated rats, when compared with the control animals. The increased serum iron level indicates that, the generation of toxic hydroxyl radicals. In the present study, we have observed that, the herbal drug treatment with *Aegle marmelos* drastically decreased the unbound serum iron. It may be through the chelating properties of flavonoids compounds of the herbal drug. *Tinospora cordifolia*, an herbal drug was reported to inhibit the Fenton mediated free radical formation through iron chelating properties (Singh et al., 2003).

Copper plays pathogenic role in primary biliary cirrhosis. The traces of soluble copper can catalyze the transformation of superoxide radical anion to highly reactive hydroxyl radical. Hydroxyl radical initiate lipid peroxidation results in oxidative damage of tissues. The level of serum copper was found to be increased in ethanol intoxicated rats. This might be due to the hepatic dysfunction and impaired biliary excretion. The therapeutic treatment with herbal drug *Aegle marmelos* decreased the level of serum iron and copper level to the normal level found in control animals. The action of standard drug Silymarin in serum iron and copper level in ethanol intoxicated rat was equivalent to the *Aegle marmelos* herbal drug. The results were presented in the Figure 8.

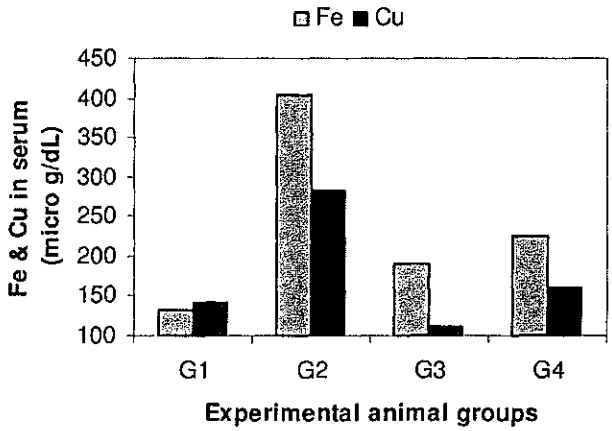

Fig 8. Effect of Aegle marmelos in serum Fe and Cu level

Conclusions

Our research studies data suggest that, there were significant variations in the observed biochemical parameters. The level of TBARS in ethanol intoxicated rats increased two fold when compared with the control animals. The levels of GSH, SOD and CAT decreased significantly in the ethanol intoxicated rats. The level of GPx was increased in the ethanol intoxicated rats. The value of vitamin E in both plasma and liver samples were less when compared with the control animals. Similarly, the value of vitamin C was also showed decreased level in plasma. Serum iron and copper levels were elevated to a higher level. The therapeutic administrations of *Aegle marmelos* leaf fine powder greatly change the biochemical parameters in the ethanol intoxicated rats and maintained well to the normal level. These results

clearly suggest that, the *Aegle marmelos* have enormous hepatoprotective value. The herbal drug has equivalent therapeutic value with the standards drug Silymarin. Further, this study creates a hope on new drug discovery in controlling liver diseases using *Aegle marmelos* as precursor. Moreover, it is very important to study the specific phytochemical compounds responsible for this hepatoprotective effect.

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